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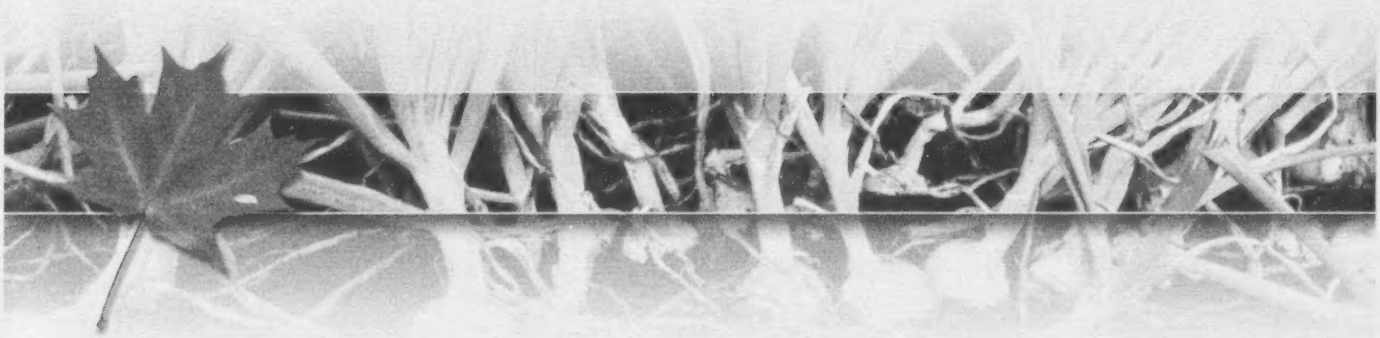

# Crop Profile for Allium Vegetables in Canada, 2012


## Prepared by:

Pesticide Risk Reduction Program
Pest Management Centre
Agriculture and Agri-Food Canada


Canada

Crop Profile for Allium Vegetables in Canada, 2012

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# Preface

National crop profiles are developed under the Pesticide Risk Reduction Program (PRRP), a joint program of Agriculture and Agri-Food Canada (AAFC) and the Pest Management Regulatory Agency (PMRA). The national crop profiles provide baseline information on crop production and pest management practices and document the pest management needs and issues faced by growers. This information is developed through extensive consultation with stakeholders.

Information on pest management practices and pesticides is provided for information purposes only. No endorsement of any pesticide or pest control technique, discussed, is implied. Product names may be included and are meant as an aid for the reader, to facilitate the identification of pesticides in general use. The use of product names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

For detailed information on growing alliums the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

Every effort has been made to ensure that the information in this publication is complete and accurate. Agriculture and Agri-Food Canada does not assume liability for errors, omissions, or representations, expressed or implied, contained in any written or oral communication associated with this publication. Errors brought to the attention of the authors will be corrected in subsequent updates.

Agriculture and Agri-Food Canada gratefully acknowledges the contributions of provincial crop specialists, industry specialists and growers in the gathering of information for this publication.

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# Crop Profile for Allium Vegetables in Canada

The allium crops are members of the Amaryllidaceae and are cultivated and consumed world-wide. In Canada, several allium crops are produced commercially including dry onion (*Allium cepa*), green onion (*A. cepa*), shallots (*A. cepa* var. *aggregatum*) and garlic (*A. sativum*). In 2012, a total of 6,775 hectares were planted to these crops (table 1) which comprised 7% of total hectares planted to vegetable crops in Canada.

The allium crops are thought to have originated in central Asia and have been cultivated for over 5,000 years. Early Spanish explorers brought onions to Central America in 1625 and growing of the crop gradually expanded northward. By the late 1800's, viable onion crops were commonplace in Canada. Leeks and garlic were introduced into North America by European settlers. However a large number of garlic varieties were collected in Russia by the USDA in 1989 and introduced into the US at that time.

Onions are bulbous, shallow rooted, monocot vegetables. Onion seed is grown biennially while the vegetable is grown as an annual. Dry onions are grown only for the fleshy bulb, with the tops being discarded. Green onions are harvested while the tops are still green and before the bulb forms. Although there are varieties of bunching onions that produce little or no bulb, growers commonly use dry onion seed to produce green onions. Leeks do not develop a pronounced bulb but are a cylindrical plant comprised of tight, flattened leaf sheaths. Shallots are comprised of 2 to 3 elongated cloves with each clove enclosed in a gold or reddish brown skin.

The garlic bulb is an aggregation of up to 20 bulblets or cloves which are enclosed in a whitish or pinkish papery skin. Hardneck varieties produce 4 to 12 cloves per bulb and softneck produce an average of 8-12 cloves per bulb. Cloves are used to vegetatively propagate the crop as garlic does not produce true seed. Hardneck varieties produce flowers heads, called scapes which have vegetative bulbils interspersed among the flowers. The bulbils may be used for propagation, however pants propagated in this way may take longer to produce a true bulb.

Onions are commonly used in salads, soups and sauces and are found in pickles and relishes. Both green onions and shallots have a milder flavour than dry onions and are often eaten raw. Shallots can be used like a green onion or the small bulb that is produced can be used like a dry onion. Onions are high in vitamin C, folate, phosphorous and potassium. The pungent odour associated with onions comes from the sulphurous oils that are contained within the onion.

Leeks have a more delicate flavour than onions and are used as a cooked vegetable and in soups and sauces. Garlic is important in many cuisines and has been used traditionally for both culinary and medicinal purposes. It is consumed as a flavourful addition to soups, stews and main courses or may be processed into a dry powder or oil for use as flavourings and supplements.

The majority of onions and shallots produced in Canada are sold domestically in the fresh market. There is a small export market, mainly to the US. Some onions are processed into

products, such as battered onion rings, chopped onions and barbeque sauces. Some cultivars of onion can also be dehydrated for soup mixes. Green onions have a very short shelf life, only 7-21 days, so it is essential to get them to market as soon as possible. Green onions are rarely processed, however shallots may be frozen or pickled.

# Crop Production

## *Industry Overview*

**Table 1. General production information**

| Crop | Dry Onion | Shallot | Leek | Garlic |
|---|---|---|---|---|
| Canadian Production (2012)[1] | 199,942 metric tonnes | 10,613 metric tonnes | 4,428 metric tonnes | 801 metric tonnes |
| | 5,436 hectares | 689 hectares | 352 hectares | 297 hectares |
| Farm gate value (2012)[1] | $65 million | $16 million | $7 million | $6 million |
| Fresh vegetables available for consumptions (2012)[2] | 9.47 kg/ person | 9.47 kg/ person | 0.36 kg/person | 0.46 kg/person |
| Export (2012)[2] | 38,936 metric tonnes[3] | 38,936 metric tonnes[3] | 987 metric tonnes | 217 metric tonnes |
| | $22 million[3] | $22 million[3] | $1.2 million | $0.4 million |
| Imports (2012)[2] | 180,632 metric tonnes[3] | 180,632 metric tonnes[3] | 4,807 metric tonnes | 18,833 metric tonnes |
| | $140 million[3] | $140 million[3] | $5.8 million | $36 million |

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database). (Accessed: 2014-01-21).

[2]Agriculture and Agri-Food Canada. Statistical Overview of the Canadian Vegetable Industry, 2012. AAFC No. 12162E-PDF.

[3]Includes onions and shallots; includes dried.

## *Production Regions*

A total of 5,436 hectares of dry onions were grown in Canada in 2012. Ontario and Quebec were the main provinces of production comprising 45% and 37% of the national acreage respectively.

A total of 689 hectares of shallots were grown in Canada in 2012, with 57% of the total national acreage in Quebec and 25% in Ontario. Leek was grown on 352 hectares in Canada in 2012 with 29% of this production occurring in Ontario. Garlic is primarily grown in Ontario (71% of national acreage) and British Columbia (16% of the national acreage). A detailed breakdown of where allium crops are grown in Canada is provided in table 2.

**Table 2. Distribution of allium crop production in Canada (2012)[1]**

| Production Regions | Dry Onion | Shallot | Leek | Garlic |
|---|---|---|---|---|
| | Planted Area 2012 (hectares) (percent national production) | Planted Area 2012 (hectares) (percent national production) | Planted Area 2012 (hectares) (percent national production) | Planted Area 2012 (hectares) (percent national production) |
| British Columbia | 101 (2%) | 24 (3%) | 19 (5%) | 49 (16%) |
| Manitoba | 209 (4%) | - | - | - |
| Ontario | 2460 (45%) | 169 (25%) | 98 (29%) | 210 (71%) |
| Quebec | 1938 (37%) | 394 (57%) | - | - |
| Nova Scotia | 253 (5%) | 6 (<1%) | 4 (1%) | - |
| **Canada** | **5436 (100%)** | **689 (100%)** | **352 (100%)** | **297 (100%)** |

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database). (Accessed: 2014-01-21).

**Figure 1. Common zone map: North American major and minor field trial regions**

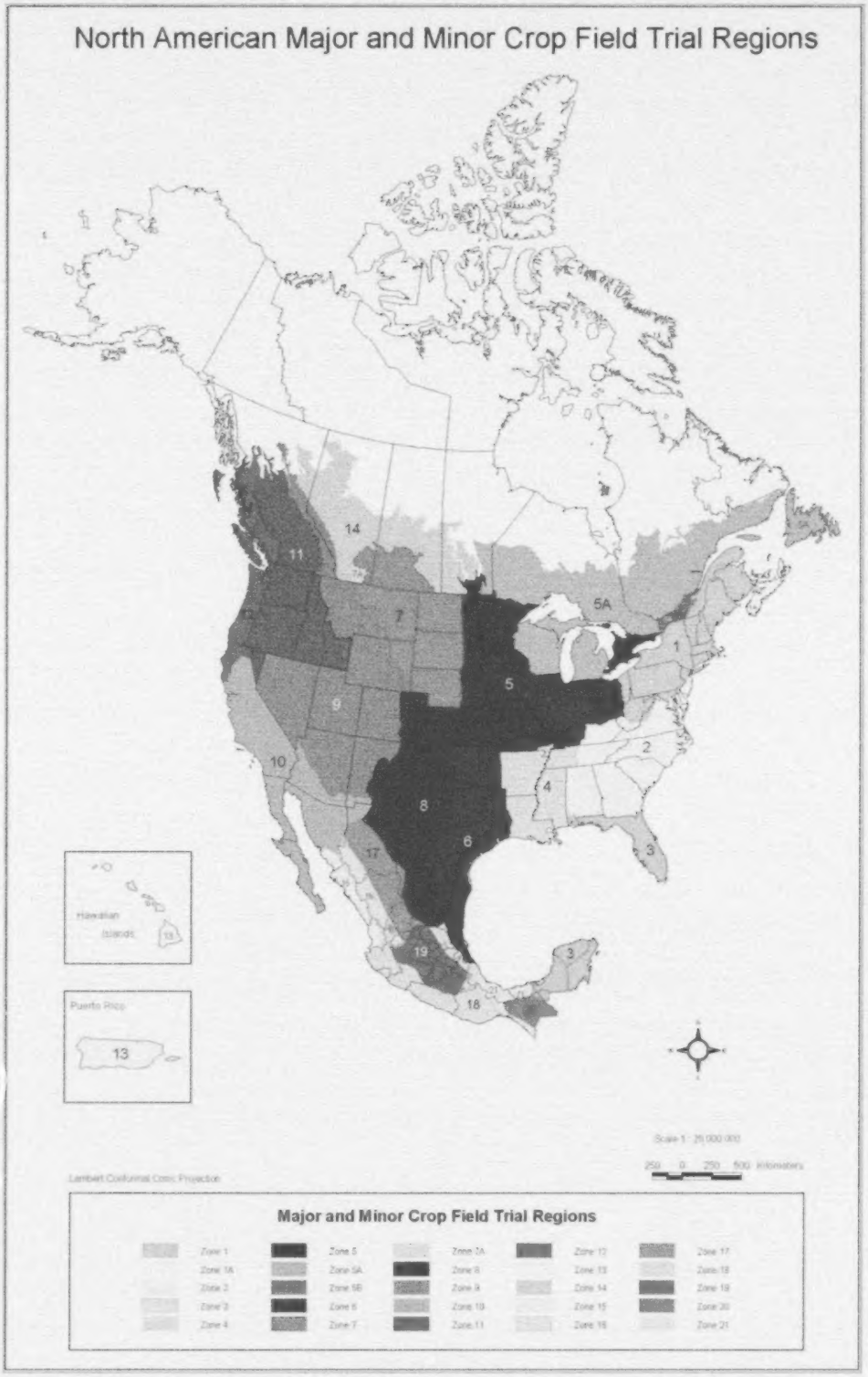

**Figure 1. Common zone map: North American major and minor field trial regions[1,2]**

The major and minor crop field trial regions were developed following stakeholder consultation and are used by the Pest Management Regulatory Agency (PMRA) and the Environmental Protection Agency of the USA to identify the regions where residue chemistry crop field trials are required to support the registration of new pesticide uses. The regions are based on a number of parameters, including soil type and climate but they do not correspond to plant hardiness zones. For additional information, please consult the PMRA Regulatory Directive 2010-05 "*Revisions to the Residue Chemistry Crop Field Trial Requirements*" (www.hc-sc.gc.ca/cps-spc/pubs/pest/_pol-guide/dir2010-05/index-eng.php).

[1]Produced for: *Asociación Mexicana de la Industria Fitosanitaria, A.C.*

[2]Produced by: Spatial Analysis and Geomatics Applications, Agriculture Division, Statistics Canada, February 2001.

## *Cultural Practices*

The allium crops grow best on fertile, well-drained soils. Sandy-loam soils are the most suitable, but most types of soils are acceptable, as long as they are relatively free of stones and other large debris and do not have a tendency to crust or become compacted. For leek, it is advisable to avoid coarse sands which become trapped in the leaves. The soil should have a pH between 6.0 and 8.4. The availability of water is very important for onion, with plants requiring up to 6 cm of moisture weekly. Alliums are commonly grown in a 4 year crop rotation. Other crops grown in the rotation vary depending on location (eg. potatoes, corn, cereals, beans or celery).

In most growing regions, onion seeds are planted using a pneumatic precision seeder at a density of 35-45 seeds per metre. Plants emerge when soil temperatures reach 13°C and optimum growth occurs when temperatures are between 20 and 25°C. Under ideal conditions, green onion and shallot crops are ready for harvest 7-10 weeks after planting, with dry onion crops taking 10-15 weeks. Cultural practices for green and dry onion are quite similar, with some minor differences. For instance, green onion and shallot crops are planted at a higher density than dry onion and some pesticides that are registered for use in dry onions are not registered for use on green onions or shallots.

Leeks may be propagated by transplants seeded in the greenhouse in the early spring and transplanted to the field in April or early May or seeded into outdoor seedbeds in the spring for transplanting mid-summer for fall harvest. A soil pH of 6.5 – 7.0 is the most suitable. The crop should be irrigated during dry conditions.

Garlic is planted in the fall and harvested the following summer. The timing of the fall planting is critical to ensure that the shoots do not emerge from the soil before winter and to ensure that adequate roots are developed to support the plant over the winter. Spacing of the cloves within a row can vary from 7 – 12 cm apart depending on the size of the bulb produced by the variety being planted. Garlic is sensitive to moisture stress and must receive 2.5 – 5.0 cm / week throughout the growing season, depending on temperature conditions. To enhance winter survival, garlic should be planted in fields which receive ample snow cover and that are

protected from the wind. Mulches may also be used to enhance winter survival. Scapes must be removed from hardneck varieties just after curling to prevent yield loss.

Major advancements in storage, irrigation and pest control in the past two decades have improved onion production practices. In the past, dry onions had only a six to eight week shelf life, which meant that they had to be moved to market quickly. Modern controlled atmosphere storages have permitted year round storage. Optimum storage temperature is just above freezing with a relative humidity of 60 to 70% and air movement to maintain uniform temperature and humidity. These conditions reduce the natural tendency of onion to sprout and have also controlled the spread of mould and other storage diseases. Advanced breeding techniques are making varieties of green onion and shallot that produce little to no bulb. Trickle irrigation is becoming popular in onion growing regions in Canada since it does not wet the onion leaves, a major factor in the spread of onion diseases.

**Table 3. Allium production and pest management schedule in Canada**

| Time of Year | Activity | Action |
|---|---|---|
| Winter (December to late March) | Soil care | Analyze soil for proper nutrients |
| | Disease management | Monitor onions in storage; apply fungicides as necessary |
| Spring (late March to May) | Plant care | Plant crop; also plant cover crop (barley) to protect soil and reduce impact of wind; irrigate as needed |
| | Soil care | Disc, plow, etc.; apply lime if needed; fertilize |
| | Disease management | Treat seeds with fungicides; fumigate fields if necessary |
| | Insect management | Monitor for onion maggot, cutworms and nematodes |
| | Weed management | Monitor for weeds and apply controls if needed |
| Summer (June to August) | Plant care | Burn off vegetative cover with selective herbicide; irrigate as needed |
| | Soil care | Cultivate / hill 2-3 weeks before harvest to achieve long white shank in green onions |
| | Disease management | Continuously monitor for disease and spray if diseases are identified. |
| | Insect management | Control onion maggots and onion thrip as needed |
| | Weed management | Monitor for weeds and apply controls if needed |
| Fall – harvest period (September to November) | Plant care | Apply sprout inhibitor; harvest onions and cure; remove cull onions. |
| | Soil care | Soil sample |
| | Disease management | Monitor onions in storage, apply fungicides as necessary |

## *Abiotic Factors Limiting Production*

### Temperature extremes

Onions are extremely temperature sensitive. They grow best when temperatures are cool and conditions are moist. Bulbs will not grow at temperatures below 12°C and bolting occurs below 10°C. When temperatures exceed 32°C growth is slowed.

### Other climatic factors

Summer droughts negatively impact onion growth. Irrigation is almost always used in onion production due to the onion crop's need for 2-6 cm of water each week. Wind can break or destroy onion greens and the crop may be lost if this is done early in the season. Wind also disturbs dry soil and exposes bulbs to the elements, leading to sunscald. Ozone injury can occur in Ontario and Quebec, reducing bulb size and increasing the incidence and severity of purple blotch and botrytis leaf blight. Hail and rain can cut and shred leaves or cause white spots, allowing diseases to enter the plant.

### Soil quality

Soils that can hold moisture are beneficial due to the crop's shallow root system. Soil crusting can delay or prevent emergence of the germinating onion seed. Manure is not recommended for fertilization because it can introduce weeds, which compete with onion plants. A soil pH between 6.0 and 8.4 is ideal. Soils low in organic matter and nutrient content or soils with poor drainage are not good for growing onions.

### Nutrients

Excessive nitrogen can lead to delayed maturity, soft bulbs and poor storage. Poor soils (low organic matter, water logged, etc.) can delay or prevent adequate growth. The lack of phosphorus will slow growth and delay maturity. A lack of potassium will make the plants more vulnerable to diseases. Inadequate copper results in soft bulbs that store poorly.

### Chemical injury

The excessive use of herbicides may cause injury to onions. If too much herbicide is applied or herbicide is applied at the wrong growth stage, burns and necrotic spots may be produced. Although this rarely kills the plant, it may stunt growth. Sprout inhibitor applied too early in the growing season on dry onions can cause bulbs to become spongy and may make them unmarketable.

## Diseases

### Key issues

- There is a need for the registration of additional reduced risk fungicides for the management of diseases including botrytis neck rot, fusarium basal rot, white rot, onion smut, downy mildew (curative products) and stemphylium leaf blight.
- There is a need for further research and development of biopesticides for diseases such as botrytis leaf blight and nematode problems.
- Forecasting systems for botrytis leaf blight and downy mildew need to be expanded at the farm and regional level. Forecasting systems available for downy mildew require further validation.
- There is a need for tools to accurately assess pesticide resistance in *Botrytis squamosa* (botrytis leaf blight) populations.
- Further research on the biology and epidemiology of botrytis neck rot is required to establish an effective management strategy for this disease.
- Additional tools for the management of onion smut, including seed treatments, in furrow/ band applications, cultural practices and biological controls, need to be developed.
- New seed treatments are needed to improve control of damping-off and for resistance management.
- There is a need for the development of alternative controls for fusarium basal rot.
- The incidence of aster yellows depends on the proportion of the leaf hopper population carrying the disease. An approach to determining when controls need to be applied is required.
- Innovative, reduced risk and cultural alternatives need to be developed for the control of bacterial soft rot.

**Table 4. Occurrence of diseases in allium crops in Canada[1,2]**

| Disease | Garlic | | Leek | | Onion | | | Shallot | |
|---|---|---|---|---|---|---|---|---|---|
| | British Columbia | Ontario | Manitoba | Quebec | Manitoba | Quebec | Nova Scotia | Manitoba | Quebec |
| Bacterial soft rot | | | | | | | | | |
| Botrytis leaf blight | | | | | | | | | |
| Botrytis neck rot | | | | | | | | | |
| Fusarium basal rot | | | | | | | | | |
| Damping-off | | | | | | | | | |
| White rot | | | | | | | | | |
| Onion smut | | | | | | | | | |
| Downy mildew | | | | | | | | | |
| Purple blotch | | | | | | | | | |
| Stemphylium leaf blight | | | | | | | | | |
| Rust | | | | | | | | | |
| Aster yellows | | | | | | | | | |
| Nematodes | | | | | | | | | |

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest is present and of concern, however little is known of its distribution, frequency and importance.

Pest not present.

Data not reported.

[1]Source: Allium stakeholders in reporting provinces.

[2]Please refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

**Table 5. Adoption of disease management practices in onion, shallot, and leek production in Canada[1]**

| Practice / Pest | | Botrytis leaf blight | Botrytis neck rot | Fusarium basal rot | Onion smut | Downy mildew | Purple blotch | Nematodes |
|---|---|---|---|---|---|---|---|---|
| Avoidance | resistant varieties | | | | | | | |
| | planting / harvest date adjustment | | | | | | | |
| | crop rotation | | | | | | | |
| | choice of planting site | | | | | | | |
| | optimizing fertilization | | | | | | | |
| | reducing mechanical damage or insect damage | | | | | | | |
| | thinning / pruning | | | | | | | |
| | use of disease-free seed, transplants | | | | | | | |
| Prevention | equipment sanitation | | | | | | | |
| | mowing / mulching / flaming | | | | | | | |
| | modification of plant density (row or plant spacing; seeding rate) | | | | | | | |
| | seeding / planting depth | | | | | | | |
| | water / irrigation management | | | | | | | |
| | end of season crop residue removal / management | | | | | | | |
| | pruning out / elimination of infected crop residues | | | | | | | |
| | tillage / cultivation | | | | | | | |
| | removal of other hosts (weeds / volunteers / wild plants) | | | | | | | |

...continued

**Table 5. Adoption of disease management practices in onion, shallot, and leek production in Canada[1] (continued)**

| Practice / Pest | | Botrytis leaf blight | Botrytis neck rot | Fusarium basal rot | Onion smut | Downy mildew | Purple blotch | Nematodes |
|---|---|---|---|---|---|---|---|---|
| Monitoring | scouting - trapping | | | | | | | |
| | records to track diseases | | | | | | | |
| | soil analysis | | | | | | | |
| | weather monitoring for disease forecasting | | | | | | | |
| | use of portable electronic devices in the field to access pest identification /management information | | | | | | | |
| | use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests | | | | | | | |
| Decision making tools | economic threshold | | | | | | | |
| | weather / weather-based forecast / predictive model | | | | | | | |
| | recommendation from crop specialist | | | | | | | |
| | first appearance of pest or pest life stage | | | | | | | |
| | observed crop damage | | | | | | | |
| | crop stage | | | | | | | |

...continued

**Table 5. Adoption of disease management practices in onion, shallot, and leek production in Canada[1] (continued)**

| Practice / Pest | | Botrytis leaf blight | Botrytis neck rot | Fusarium basal rot | Onion smut | Downy mildew | Purple blotch | Nematodes |
|---|---|---|---|---|---|---|---|---|
| Suppression | pesticide rotation for resistance management | | | | | | | |
| | soil amendments | | | | | | | |
| | biological pesticides | | | | | | | |
| | controlled atmosphere storage | | | | | | | |
| | targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.) | | | | | | | |
| New practices (by province) | spore trapping (Quebec) | | | | | | | |

**This practice is used to manage this pest by at least some growers in the province.**

**This practice is not used by growers in the province to manage this pest.**

**This practice is not applicable for the management of this pest**

**Information regarding the practice for this pest is unknown.**

[1]**Source: Allium crop stakeholders in reporting provinces (Manitoba, Quebec and Nova Scotia).**

...continued

**Table 6. Adoption of disease management practices in garlic production in Canada[1] (continued)**

| Practice / Pest | | Botrytis leaf blight | Botrytis neck rot | Fusarium basal rot | Onion smut | Downy mildew | Purple blotch | Nematodes |
|---|---|---|---|---|---|---|---|---|
| Avoidance | resistant varieties | | | | | | | |
| | planting / harvest date adjustment | | | | | | | |
| | crop rotation | | | | | | | |
| | choice of planting site | | | | | | | |
| | optimizing fertilization | | | | | | | |
| | reducing mechanical damage or insect damage | | | | | | | |
| | thinning / pruning | | | | | | | |
| | use of disease-free seed, transplants | | | | | | | |
| Prevention | equipment sanitation | | | | | | | |
| | mowing / mulching / flaming | | | | | | | |
| | modification of plant density (row or plant spacing; seeding rate) | | | | | | | |
| | seeding / planting depth | | | | | | | |
| | water / irrigation management | | | | | | | |
| | end of season crop residue removal / management | | | | | | | |
| | pruning out / elimination of infected crop residues | | | | | | | |
| | tillage / cultivation | | | | | | | |
| | removal of other hosts (weeds / volunteers / wild plants) | | | | | | | |

...continued

**Table 6. Adoption of disease management practices in garlic production in Canada[1] (continued)**

| Practice / Pest | | Botrytis leaf blight | Botrytis neck rot | Fusarium basal rot | Onion smut | Downy mildew | Purple blotch | Nematodes |
|---|---|---|---|---|---|---|---|---|
| Monitoring | scouting - trapping | | | | | | | |
| | records to track diseases | | | | | | | |
| | soil analysis | | | | | | | |
| | weather monitoring for disease forecasting | | | | | | | |
| | use of portable electronic devices in the field to access pest identification /management information | | | | | | | |
| | use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests | | | | | | | |
| Decision making tools | economic threshold | | | | | | | |
| | weather / weather-based forecast / predictive model | | | | | | | |
| | recommendation from crop specialist | | | | | | | |
| | first appearance of pest or pest life stage | | | | | | | |
| | observed crop damage | | | | | | | |
| | crop stage | | | | | | | |

...continued

**Table 6. Adoption of disease management practices in garlic production in Canada[1] (continued)**

| Practice / Pest | | Botrytis leaf blight | Botrytis neck rot | Fusarium basal rot | Onion smut | Downy mildew | Purple blotch | Nematodes |
|---|---|---|---|---|---|---|---|---|
| Suppression | pesticide rotation for resistance management | | | | | | | |
| | soil amendments | | | | | | | |
| | biological pesticides | | | | | | | |
| | controlled atmosphere storage | | | | | | | |
| | targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.) | | | | | | | |
| New practices (by province) | spore trapping (Quebec) | | | | | | | |
| This practice is used to manage this pest by at least some growers in the province. | | | | | | | | |
| This practice is not used by growers in the province to manage this pest. | | | | | | | | |
| This practice is not applicable for the management of this pest. | | | | | | | | |
| Information regarding the practice for this pest is unknown. | | | | | | | | |

[1]Source: Allium crop stakeholders in reporting provinces (Ontario).

**Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Target Site[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|---|
| Seed treatments | | | | | | |
| carbathiin + thiram (onion only) | N/A + dithio-carbamate and relative | N/A + multi-site contact activity | N/A + multi-site contact activity | 7 + M3 | N/A + RE | Smut |
| fludioxonil | phenylpyrrole | E2: signal transduction | MAP/Histidine-Kinase in osmotic signal transduction (os-2, HOG1) | 12 | RE | Seed-borne and soil-borne diseases caused by *Fusarium* spp. (including seedling diseases due to *F. graminearum*) and *Rhizoctonia* spp. |
| metalaxyl-m | acylalanine | A1: nucleic acids synthesis | RNA polymerase I | 4 | R | Damping-off (*Pythium* spp.) |
| thiram (dry bulb onion only) | dithio-carbamate and relative | Multi-site contact activity | Multi-site contact activity | M3 | RE | Smut (*Urocystis magica*) |
| Soil treatments | | | | | | |
| *Bacillus subtilis* (strain, souche QST 713) | *Bacillus subtilis* and the fungicidal lipopeptides they produce | F6: lipids and membrane synthesis | microbial disrupters of pathogen cell membranes | 44 | R | Rhizoctonia damping-off and root rot (*Rhizoctonia solani*), pink root (*Phoma terrestris*), pythium root rot (*Pythium* spp.) |
| diallyl disulfied and related sulfides | - | Biological stimulator for the germination of white rot microsclerotia | | - | | White rot (*Sclerotium cepivorum*) |
| Foliar treatments | | | | | | |
| ametoctradin | triazolo-pyrimidylamine | C8: respiration | C8: complex III: cytochrome bc1 (ubiquinone reductase) at Q x (unknown) site | 45 | R | Downy mildew (*Peronospora destructor*) |

...continued

**Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada (continued)**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Target Site[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|---|
| Foliar treatments | | | | | | |
| ametoctradin + dimethomorph | triazolo-pyrimidylamine + cinnamic acide amide | C8: respiration + H5: cell wall biosynthesis | C8: complex III: cytochrome bc1 (ubiquinone reductase) at Q x (unknown) site + cellulose synthase | 45 + 40 | R + RES | Downy mildew (*Peronospora destructor*) |
| azoxystrobin | methoxy-acrylate | C3. respiration | complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) | 11 | R | Seed rot/ pre-emergence damping-off (*Rhizoctonia solani*) |
| azoxystrobin + difenoconazole | methoxy-acrylate + triazole | C3. respiration + G1: sterol biosynthesis in membranes | complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + C14-demethylase in sterol biosynthesis (erg/cyp51) | 11 + 3 | R + RES | Purple blotch (*Alternaria porri*), leaf blotch (*Cladosporium allii-cepae*), downy mildew (*Peronspora destructor*), botrytis leaf blight (*Botrytis squamosa*), suppression of stemphylium leaf blight (*Stemphylium vesicarium*) |
| *Bacillus subtilis* (strain souche QST 713) | *Bacillus subtilis* and the fungicidal lipopeptides they produce | F6: lipids and membrane synthesis | microbial disrupters of pathogen cell membranes | 44 | R | Botrytis neck rot (*Botrytis allii*), botrytis leaf blight (*Botrytis squamosa*), downy mildew (*Peronospora destructor*) |
| boscalid | pyridine carboxamide | C2. respiration | complex II: succinate-dehydro-genase | 7 | R | Alternaria purple blotch (*Alternaria porri*), botrytis leaf blight (*Botrytis squamosa*) |

...continued

**Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada (continued)**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Target Site[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|---|
| Foliar treatments | | | | | | |
| boscalid + pyraclostrobin | pyridine carboxamide | C2. respiration | complex II: succinate-dehydro-genase | 7 | R | Alternaria purple blotch (*Alternaria porri*), botrytis leaf blight (*Botrytis squamosa*), suppression of downy mildew (*Peronospora destructor*) |
| chlorothalonil (dry bulb and green bunching onion only) | chloronitrile (phthalonitrile) | Multi-site contact activity | Multi-site contact activity | M5 | RE | Botrytis leaf blight (*Botrytis squamosa*) |
| cyprodinil + fludioxonil (dry bulb and green onion and onions grown for seed only) | anilino-pyrimidine + phenylpyrrole | D1: amino acids and protein synthesis + E2: signal transduction | methionine biosynthesis (proposed) (cgs gene) + MAP/Histidine-kinase osmotic signal transduction (os-2, HOG1) | 9 + 12 | R + RE | Botrytis leaf blight or blast (*Botrytis squamosa*), suppression of purple blotch (*Alternaria porri*) |
| dicloran (onion and garlic only) | aromatic hydrocarbon | F3: lipids and membrane synthesis | lipid peroxidation (proposed) | 14 | R | White rot (*Sclerotium cepivorum*) |
| difenoconazole | triazole | G1: sterol biosynthesis in membranes | C14- demethylase in sterol biosynthesis (erg11/cyp51) | 3 | RES | Purple blotch (*Alternaria porri*) |
| dimethomorph | cinnamic acid amide | H5: cell wall biosynthesis | cellulose synthase | 40 | RE | Suppression of downy mildew (*Peronospora destructor*) |
| fenamidone | imidazolinone | C3. respiration | complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) | 11 | R | Suppression of downy mildew (*Peronospora destructor*) |

...continued

**Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada (continued)**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Target Site[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|---|
| Foliar treatments | | | | | | |
| fosetyl-Al (onion only) | ethyl phosphonate | Unknown mode of action | | 33 | RE | Downy mildew (*Peronospora destructor*) and purple blotch (*Alternaria porri*) |
| iprodione (garlic only) | dicarboximide | E3: signal transduction | MAP/Histidine-Kinase in osmotic signal transduction (os-1, Daf1) | 2 | RE | Green mould (*Penicillium corymbiferum*) |
| iprodione (onion only) | dicarboximide | E3: signal transduction | MAP/Histidine-Kinase in osmotic signal transduction (os-1, Daf1) | 2 | RE | Botrytis leaf blight (*Botrytis squamosa*) |
| mancozeb (dry bulb onion only) | dithio-carbamate and relatives | Multi-site contact activity | Multi-site contact activity | M3 | RE | Botrytis leaf blight (*Botrytis squamosa*) and neck rot (*B. allii*), downy mildew (*Peronospora destructor*), purple blotch (*Alternaria porri*), onion smut (*Urocystis magica*) |
| mandipropamid (onion, garlic, shallot only) | mandelic acid amide | H5: cell wall biosynthesis | cellulose synthase | 40 | R | Downy mildew (*Peronospora destructor*) |
| metalaxyl-m + mancozeb | acylalanine + dithio-carbamate and relatives | A1: nucleic acids synthesis + multi-site contact activity | RNA polymerase I + multi-site contact activity | 4 + M3 | R + RES | Downy mildew (*Peronospora destructor*) |
| penthiopyrad | pyrazole carboxamide | C2. respiration | complex II: succinate-dehydro-genase | 7 | R | Suppression of botrytis fleck (*Botrytis cinerea*) and purple blotch (*Alternaria porri*) |

...continued

**Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada (continued)**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Target Site[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|---|
| Foliar treatments | | | | | | |
| pyraclostrobin | methoxy-carbamate | C3. respiration | complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) | 11 | R | Alternaria purple blotch (*Alternaria porri*), downy mildew (*Peronospora destructor*) |
| pyrimethanil | anilino-pyrimidine | D1: amino acids and protein synthesis | methionine biosynthesis (proposed) (cgs gene) | 9 | R | Botrytis leaf blight (*Botrytis squamosa, B. cinerea*), purple blotch (*Alternaria porri*), neck rot (*B. allii*) |

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 20, 2014, on onion, shallot, leek and garlic unless otherwise specified. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Fungicide Resistance Action Committee. *FRAC Code List 2013: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed January 2014).

[3]PMRA re-evaluation status: R - full registration RE (yellow) - under re-evaluation , RES (yellow) - under special review as published in PMRA Re-evaluation note REV2013-06, *Special Review Initiation of 23 Active Ingredients*, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of November 15, 2013.

## Bacterial soft rot (*Erwinia carotovora*)

### *Pest information*

*Damage:* Soft rot commonly occurs as a result of damage caused by other diseases or insects. Once the soft rot bacterium has entered the plant it affects the scales of the onion, causing them to become pale and watery and eventually breakdown into an odorous sticky material, making the bulb unmarketable.

*Life cycle:* The pathogen survives in the soil on crop residues. Rain and irrigation transfer the bacterium to the plant where it enters through wounds. The development of soft rot is favoured by heavy rain and high humidity. Once inside a plant, it can spread rapidly if temperature and moisture is high. The bacterium can continue to spread and multiply in storage.

### *Pest management*

*Cultural controls:* Since bacterial soft rot enters the onion through wounds, it is important to minimize insect damage and avoid mechanical injury to the crop. Soils should be well drained and irrigation should be reduced as the crop matures. Infected onions should be graded out before they are put into storage. Storage facilities should be monitored often and proper temperature and moisture conditions maintained.

*Resistant cultivars:* None identified.

*Chemical controls:* There are no registered products for control of the disease in the field however several copper compounds are available for treatment in storage.

### *Issues for Bacterial Soft Rot*

1. Innovative, reduced risk and cultural alternatives need to be developed for the control of bacterial soft rot.

## Botrytis leaf blight (*Botrytis squamosa*)

### *Pest information*

*Damage:* The first symptom of botrytis leaf blight is the appearance of grey spots on leaves early in the growing season. The spots gradually enlarge and may crack, exposing the inner tissues of the leaf and providing a site of entry for other pathogens. Onions can tolerate losses of up to 10% of their photosynthetic area before yields are reduced. As the disease progresses the plant dies back, resulting in smaller bulbs that do not dry properly for storage. Botrytis leaf blight rarely kills the plant however it can cause severe economic damage by reducing yields.

*Life cycle:* Botrytis overwinters as sclerotia in the soil, in field debris or on cull piles. Spores are produced in the spring, when temperatures rise above 3°C. The spores are spread by wind to new onion plants where they cause new infections when conditions are moist for an extended period of time.

### *Pest management*

*Cultural controls:* A three year crop rotation with crops unrelated to onion, such as carrot or celery, should be used. Onion refuse should be removed from the field and cull piles should not be kept in the field. Irrigation should be avoided when the disease has been reported in the area. Reducing planting density and avoiding high rates of nitrogen fertilizer application will minimize disease development. BOTCAST, a blight prediction model is available to help determine the need for fungicide application.

*Resistant cultivars:* None identified.

*Chemical controls:* Protectant fungicides sprayed throughout the growing season often provide adequate control.

### *Issues for botrytis leaf blight*

1. There are several forecasting systems for onion blight. However, there is a need to expand the application of these prediction systems at the farm and regional level and to implement new technology such as spore trapping.
2. There is a need for the development of biopesticides for the management of botrytis leaf blight.
3. There is a need to assess levels of pesticide resistance in botrytis populations.

## Botrytis neck rot (*Botrytis aclada*)

### *Pest information*

*Damage:* Botrytis neck rot is an important storage disease of dry onions. Onions are infected through the neck when the tops are cut prior to storage, or through bruises. Symptoms of the disease begin with sunken brown scales around the neck of the onion. A definite margin becomes visible between healthy and diseased tissue. Over time, as the pathogen spreads throughout the bulb, mycelia begin to appear. The onion becomes blackened and mummified, making it unmarketable. The mycelium can spread to other bulbs in storage. The disease is not as much of a concern for green onion and shallot since they are not stored for any length of time.

*Life cycle:* Sclerotia overwinter in soil or on culled onions and may survive in the soil for up to 4 years. In the spring, conidia are produced which are carried by the wind to the onion crop. The disease is more prevalent in cool, wet growing seasons.

### *Pest management*

*Cultural controls:* Proper field sanitation is the key to controlling neck rot. Cull onions or cull piles should not be left in the field, as they can be a source of the inoculum. A three year crop rotation with crops unrelated to onion, such as carrot or celery, should be used. Where feasible, onion fields should be separated by at least 5 kilometers. Harvest should be done when conditions are dry. Onion bulbs should be cured in the field before storing. Care should be taken to not bruise or damage the bulbs during harvest or transportation. The progression

of the disease is slowed in storage when the temperature is maintained at 0°C with 60-70 % humidity.

*Resistant cultivars:* Most onion varieties are susceptible to the disease. Some red onion varieties are less susceptible.

*Chemical controls:* Almost all of the onion seed planted in Canada is treated with fungicide to control onion smut, and these treatments are also effective against neck rot.

***Issues for botrytis neck rot***

1. There are only a few foliar fungicides registered for botrytis leaf blight. Further studies are required to determine whether these fungicides are also effective against neck rot.
2. Further research into the biology of the pathogen and epidemiology of the disease is needed to establish an effective management strategy for neck rot.

## Onion smut (*Urocystis magica*)

***Pest information***

*Damage:* Onion smut is common in all onion producing areas of the world. The pathogen attacks the onion seedling early, causing the cotyledon to become thick and dark. Spores develop in pustules in the leaves. The leaves become distorted and often split, releasing the spores. Seedlings are often killed before the third and fourth leaves are produced. The pathogen becomes systemic in plants that do survive to harvest and gives rise to dark pustules on the bulbs. Bacterial soft rot commonly infects onions that have previously been infected with onion smut.

*Life cycle:* Onion smut is very persistent, and can survive in the soil as spores (teliospores) up to 15 years. Spores germinate and can infect seedlings from about the second day after seed germination until the emergence of the first true leaves, a period of about 15 days. Conditions which slow the growth of the onion seedling can prolong this period of susceptibility. The movement of infested soil, water and infected plant parts will spread the pathogen.

***Pest management***

*Cultural controls:* Seeds should be planted as shallowly as possible for rapid emergence, to reduce the period of seedling susceptibility to infection. Tillage machinery should be cleaned between fields in order to avoid spreading the disease to new areas. When possible, planting should be delayed until soil temperatures rise to promote rapid germination of seeds. Crop rotation is not effective in controlling onion smut.

*Resistant cultivars:* None available.

*Chemical controls:* Refer to "Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada".

### *Issues for onion smut*

1. There is a need for the registration of new reduced risk fungicides for the improved control of smut and for resistance management.
2. Alternative methods of fungicide application (eg. seed treatment, furrow/band application) need to be developed for the control of onion smut.
3. There is a need for the development of alternative (cultural and biological) disease management approaches for onion smut.

## Downy mildew (*Peronospora destructor*)

### *Pest information*

*Damage:* Downey mildew produces a purple velvet-like growth on the leaves followed by white blotches of fungal growth. As the disease progresses, the leaves yellow and die. The bulbs of affected plants are smaller, do not dry properly and green onions that are infected, are unmarketable.

*Life cycle:* In the spring, new plants and leaves are infected by spores produced on onion culls and volunteer onion plants. Infected leaves give rise to new generations of spores which cause new infections.

### *Pest management*

*Cultural controls:* Equipment should be cleaned after use and cull piles should be removed from the field. Related crops should not be grown near onion fields. A crop rotation of 2-3 years is beneficial. Onion fields should be well drained. Weed control increases air circulation and shortens the time dew stays on foliage making conditions less favourable for disease development. The DOWNCAST forecasting model is available to growers to predict disease outbreaks and the need for protective fungicide treatments.

*Resistant cultivars:* None available.

*Chemical controls:* Refer to "Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada".

### *Issues for downy mildew*

1. There is a need to validate and expand forecasting systems currently available for downy mildew at the farm and regional level and to implement new technology such as spore trapping.
2. There is a need for the registration of fungicides with curative effects.

## Purple blotch (*Alternaria porri*)

### *Pest information*

*Damage:* Purple blotch causes oval, purple lesions up to 3 cm in diameter on onion leaves, eventually killing them. In storage, the disease can cause bulb rot.

*Life cycle:* Conidia are produced in infected crop residues in the spring and are spread to new tissues by wind or rain splashing. Free moisture is required on leaves for infection to occur. The pathogen usually infects leaves damaged by other diseases, insects or abiotic factors. The disease is most prevalent during warm, wet growing seasons.

### *Pest management*

*Cultural controls:* Cull piles should be removed from the field. A 3-4 year crop rotation with crops, such as potato, carrot and lettuce, should be maintained. Harvest should be done when conditions are dry.

*Resistant cultivars:* Spanish onions are very susceptible. Yellow onion cultivars are less susceptible.

*Chemical controls:* Many broad spectrum fungicides provide control of purple blotch. Refer to "Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada".

### *Issues for purple blotch*

None identified.

## Stemphylium leaf blight (*Stemphylium vesicarium*)

### *Pest information*

*Damage:* Stemphylium leaf blight results in tan, water-soaked, leaf spots that eventually coalesce, completely blighting the leaves. The leaf dieback may impact bulb size and quality.

*Life cycle:* The fungus is a secondary invader of damaged or diseased leaves. Conidia are produced in leafspots. Warm temperatures (18-25°C) and long periods of leaf wetness (in excess of 16 hours) are conducive to disease development.

### *Pest management*

*Cultural controls:* Controlling other diseases and insect problems on onion will reduce the potential for leaf blight development. Following a crop rotation of 3 years with non-host crops and eliminating crop debris and cull piles from the field, sources of inoculum, will also help to reduce disease development. Factors which help to reduce the duration of leaf wetness such as increased plant spacing and timing irrigation practices for the morning will also help to reduce leaf blight.

*Resistant cultivars:* None available.

*Chemical controls:* Refer to "Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada".

### *Issues for stemphylium leaf blight*

1. There are no fungicides registered for the control of stemphylium leaf blight. The registration of reduced risk fungicides to control this disease is required.

## Damping-off (*Pythium* spp., *Rhizoctonia* spp., *Fusarium* spp.)

### *Pest information*

*Damage:* Cold, wet soils can result in damping-off of seedlings. The disease is caused by *Pythium*, *Rhizoctonia* or *Fusarium* fungi, either alone or in combination. Seedlings may collapse as a result of lesions at the soil line or may die before emergence from the soil.

*Life cycle:* Soil-borne fungal pathogens that cause damping-off can persist for many years in soil and infected crop debris. Spores and fungal resting structures germinate in response to root exudates and infect plant seeds and roots under conditions of excessive soil moisture and poor drainage.

### *Pest management*

*Cultural controls:* A 5 year crop rotation with non-host crops will reduce the incidence of damping-off. Onions should be planted into well-drained soil and environmental stresses minimized to reduce the potential for the development of damping-off.

*Resistant cultivars:* None identified.

*Chemical controls:* The use of seed treatments will reduce disease development.

### *Issues for damping-off*

1. New seed treatments are needed to improve the control of damping off and for resistance management.

## Fusarium basal rot (*Fusarium oxysporum*)

### *Pest information*

*Damage:* Basal rot results in a pinkish-brown rot at the base of the bulb and root rot. Early symptoms include yellowing and tip dieback of onion leaves. Eventually, the basal rot grows into the bulb and leaves may die. Depending on conditions, mycelium may or may not be visible in the rotted tissues. Plant growth and symptoms may be non-symmetrical on each plant, as the infection may develop on only one side of the basal plate. Symptoms of late season infection may not be apparent until storage.

*Life cycle:* The fungus lives in the soil and is spread by water, wind and the movement of contaminated soil. Fusarium commonly enters through damage caused by pests such as the onion maggot. The fungus can spread rapidly in warm soils, but is not usually an issue in cool growing seasons. Storage facilities kept at cool temperatures limit the development of the fungus during storage.

***Pest management***

*Cultural controls:* Fields with a history of basal rot should be avoided. A three year crop rotation with crops unrelated to onion, such as carrot or celery, should be used. Dry onions should be cured in the field before being put in storage. All damaged, bruised or infected bulbs should be discarded before storing. Storage facilities should be kept at 0°C and 60-70 % relative humidity to slow the progression of the disease.

*Resistant cultivars:* Tolerant varieties include 'Canada Maple', 'Granite' and 'Valiant'.

*Chemical controls:* The control of onion maggot with registered insecticides can help reduce the incidence of the disease.

***Issues for fusarium basal rot***

1. There is a need for the registration of reduced risk fungicides for the control of fusarium basal rot.
2. There is a need for the development of alternative control methods for fusarium basal rot.

## White rot (*Sclerotium cepivorum*)

***Pest information***

*Damage:* White rot causes a watery rot of the onion bulbs. Initial symptoms in the field include the yellowing of onion leaf tips, followed by leaf dieback and death. White mycelium grows around the base of the bulb and black sclerotia are formed. Eventually the entire plant is killed. Occasionally, white rot develops late in the growing season with symptoms on dry onion not being observed until the bulbs are in storage.

*Life cycle:* Only members of *Allium* spp. are attacked by this pathogen. Sclerotia can survive in the soil for many years and germinate only when *Allium* plant roots are in proximity. Sclerotia germinate and infect onions through roots and bulb wounds. Plant to plant spread can occur if plants are in close proximity. The disease is favoured by cool, damp summers as temperatures above 20°C slow infection. The disease is spread between fields in soil moved by wind, equipment and irrigation water. It can be introduced into new areas, through infected onion sets and transplants.

***Pest management***

*Cultural controls:* Thorough sanitation is necessary to minimize disease and prevent its spread. Sanitation practices include the use of disease-free onion sets and transplants, clean machinery and pallet boxes, the use of non-contaminated irrigation water and the removal of

infected plant material from the field. Organic soils can be flooded for 1 month during the spring to encourage sclerotial decay

*Resistant cultivars:* None identified.

*Chemical controls:* Refer to "Table 7. Fungicides and biofungicides registered for disease management in allium crop production in Canada".

***Issues for white rot***

1. There are no effective fungicides registered for use on white rot.

## Aster yellows (Aster yellows phytoplasma)

***Pest information***

*Damage:* Aster yellows causes a foliar yellowing and streaking of the leaves. In infected plants grown for seed, the floral cluster can become malformed and sterile.

*Life cycle:* The aster yellows phytoplasma overwinters in leafhoppers and perennial host plants. After acquiring the pathogen, 10 days are required before leafhoppers are able to transmit the disease to new plants. An insect may remain active and continue to spread the disease for more than 100 days after acquiring the pathogen.

***Pest management***

*Cultural controls:* Perennial weeds should be controlled in the crop, in adjacent fields and field edges as they can serve as overwintering hosts for the phytoplasma. Leafhopper populations must be controlled. Early planting is important to establish plants before infection is a concern. The monitoring of leafhoppers and their migration from field to field is important.

*Resistant cultivars:* None available.

*Chemical controls:* There are no chemical controls for aster yellows. Refer to "Table 11. Insecticides and bioinsecticides registered for the management of insect pests in allium crop production in Canada" for products registered for the control of leafhoppers

***Issues for aster yellows***

1. The prevalence of aster yellows in a crop is affected by the numbers of leafhoppers and the proportion of which are carrying the phytoplasma. An economic threshold needs to be developed to determine when leafhopper controls need to be implemented.

## Nematodes: Stem and bulb nematode *(Ditylenchus dipsaci) and* root-lesion nematode (*Pratylenchus penetrans)*

### *Pest information*

*Damage:* Nematodes cause yellowing and stunting of onion crops. They can cause galls on roots and cause roots to become necrotic. Bulbs can be deformed, discolored, spongy and bloated and may split if dried. This damage can occur in the field as well as in storage. Although nematodes may not kill a plant, their damage predisposes the onions to infection by secondary fungi and bacteria. Yields can be reduced by as much as 10%.

*Life cycle:* The adult nematode can lay as many as 80 eggs, which hatch in a few weeks. Juvenile nematodes develop through three moults before they become adults. Root lesion nematodes require 4 to 8 weeks to complete their life cycle, depending on soil moisture and temperature. Nematodes can become dormant and survive in the soil for many years.

### *Pest management*

*Cultural controls:* A three year crop rotation should be followed with non-host crops. Sanitation of machinery is important as soil transfer is a common method of spreading the infestation. Cull piles should not be left in the field. Many nematodes are inactive at cooler temperatures, so planting at these times may limit damage to new seedlings. Before planting, soil samples can be tested to determine whether nematode populations are at damaging levels. Species identification is important, as some species will not harm onions.

*Resistant cultivars:* None identified.

*Chemical controls:* Nematodes rarely cause economic damage and are not commonly chemically controlled.

### *Issues for nematodes*

1. There is a need for further research on pathogenic fungi with potential for the biological control of nematodes.

## Insects and Mites

### Key issues

1. The potential for the development of pesticide resistance in onion maggot and onion thrips is of concern. There is a need for the registration of additional chemistries for these pests for resistance management.
2. Studies to determine the best approach to insecticide application (water quantity, application timing, use of adjuvant, nozzle type, etc.) are required to improve thrips control.
3. There is a need for the registration of reduced risk products and alternative controls for leek moth for use in both conventional and organic production systems.
4. A model to predict the timing of treatments for leek moths needs to be developed.
5. There is a need to develop a decision model/ economic threshold to determine when leafhopper (the vector of aster yellows) control is needed.
6. There is a need for the development of an effective, integrated approach to the management of wireworms including the registration of reduced risk pesticides and non-chemical methods.

**Table 8. Occurrence of insect pests in allium crops in Canada[1,2]**

| Insect | Garlic | | Leek | | Onion | | | Shallot | |
|---|---|---|---|---|---|---|---|---|---|
| | British Columbia | Ontario | Manitoba | Quebec | Manitoba | Quebec | Nova Scotia | Manitoba | Quebec |
| Onion Maggot | | | | | | | | | |
| Onion Thrips | | | | | | | | | |
| Cutworms | | | | | | | | | |
| Black cutworm | | | | | | | | | |
| Dark sided cutworm | | | | | | | | | |
| Leafminer | | | | | | | | | |
| Aster Leafhopper | | | | | | | | | |
| Leek moth | | | | | | | | | |
| Wireworms | | | | | | | | | |

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest is present and of concern, however little is known of its distribution, frequency and importance.

Pest not present.

Data not reported.

[1]Source: Allium stakeholders in reporting provinces.

[2]Please refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

**Table 9. Adoption of insect management practices in onion, shallot, and leek production in Canada[1]**

| Practice / Pest | | Onion maggot | Onion thrips | Cutworms | Aster leafhopper | Leek moth |
|---|---|---|---|---|---|---|
| Avoidance | resistant varieties | | | | | |
| | planting / harvest date adjustment | | | | | |
| | crop rotation | | | | | |
| | choice of planting site | | | | | |
| | optimizing fertilization | | | | | |
| | reducing mechanical damage | | | | | |
| | thinning / pruning | | | | | |
| | trap crops / perimeter spraying | | | | | |
| | physical barriers | | | | | |
| Prevention | equipment sanitation | | | | | |
| | mowing / mulching / flaming | | | | | |
| | modification of plant density (row or plant spacing; seeding rate) | | | | | |
| | seeding depth | | | | | |
| | water / irrigation management | | | | | |
| | end of season crop residue removal / management | | | | | |
| | pruning out / removal of infested material | | | | | |
| | tillage / cultivation | | | | | |
| | removal of other hosts (weeds / volunteers / wild plants) | | | | | |
| Monitoring | scouting - trapping | | | | | |
| | records to track pests | | | | | |
| | soil analysis | | | | | |
| | use of portable electronic devices in the field to access pest identification /management information | | | | | |
| | use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests | | | | | |
| | grading out infected produce | | | | | |

...continued

**Table 9. Adoption of insect management practices in onion, shallot, and leek production in Canada[1] (continued)**

| Practice / Pest | | Onion maggot | Onion thrips | Cutworms | Aster leafhopper | Leek moth |
|---|---|---|---|---|---|---|
| Decision making tools | economic threshold | | | | | |
| | weather / weather-based forecast / predictive model (eg. degree day modelling) | | | | | |
| | recommendation from crop specialist | | | | | |
| | first appearance of pest or pest life stage | | | | | |
| | observed crop damage | | | | | |
| | crop stage | | | | | |
| Suppression | pesticide rotation for resistance management | | | | | |
| | soil amendments | | | | | |
| | biological pesticides | | | | | |
| | arthropod biological control agents | | | | | |
| | beneficial organisms and habitat management | | | | | |
| | ground cover / physical barriers | | | | | |
| | pheromones (eg. mating disruption) | | | | | |
| | sterile mating technique | | | | | |
| | trapping | | | | | |
| | targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.) | | | | | |
| Crop specific practices | floating row covers | | | | | |

...continued

**Table 9. Adoption of insect management practices in onion, shallot, and leek production in Canada[1] (continued)**

| Practice / Pest | | Onion maggot | Onion thrips | Cutworms | Aster leafhopper | Leek moth |
|---|---|---|---|---|---|---|
| New practices (by province) | kairomone (Quebec) | | | | | |
| | seed treatments (Quebec) | | | | | |

This practice is used to manage this pest by at least some growers in the province.
This practice is not used by growers in the province to manage this pest.
This practice is not applicable for the management of this pest.
Information regarding the practice for this pest is unknown.

[1]Source: Allium crop stakeholders in reporting provinces (Manitoba, Quebec and Nova Scotia).

**Table 10. Adoption of insect management practices in garlic production in Canada[1]**

| Practice / Pest | | Onion maggot | Onion thrips | Cutworms | Aster leafhopper | Leek moth |
|---|---|---|---|---|---|---|
| Avoidance | resistant varieties | | | | | |
| | planting / harvest date adjustment | | | | | |
| | crop rotation | | | | | |
| | choice of planting site | | | | | |
| | optimizing fertilization | | | | | |
| | reducing mechanical damage | | | | | |
| | thinning / pruning | | | | | |
| | trap crops / perimeter spraying | | | | | |
| | physical barriers | | | | | |
| Prevention | equipment sanitation | | | | | |
| | mowing / mulching / flaming | | | | | |
| | modification of plant density (row or plant spacing; seeding rate) | | | | | |
| | seeding depth | | | | | |
| | water / irrigation management | | | | | |
| | end of season crop residue removal / management | | | | | |
| | pruning out / removal of infested material | | | | | |
| | tillage / cultivation | | | | | |
| | removal of other hosts (weeds / volunteers / wild plants) | | | | | |
| Monitoring | scouting - trapping | | | | | |
| | records to track pests | | | | | |
| | soil analysis | | | | | |
| | use of portable electronic devices in the field to access pest identification /management information | | | | | |
| | use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests | | | | | |
| | grading out infected produce | | | | | |

...continued

**Table 10. Adoption of insect management practices in garlic production in Canada[1] (continued)**

| Practice / Pest | | Onion maggot | Onion thrips | Cutworms | Aster leafhopper | Leek moth |
|---|---|---|---|---|---|---|
| Decision making tools | economic threshold | | | | | |
| | weather / weather-based forecast / predictive model (eg. degree day modelling) | | | | | |
| | recommendation from crop specialist | | | | | |
| | first appearance of pest or pest life stage | | | | | |
| | observed crop damage | | | | | |
| | crop stage | | | | | |
| Suppression | pesticide rotation for resistance management | | | | | |
| | soil amendments | | | | | |
| | biological pesticides | | | | | |
| | arthropod biological control agents | | | | | |
| | beneficial organisms and habitat management | | | | | |
| | ground cover / physical barriers | | | | | |
| | pheromones (eg. mating disruption) | | | | | |
| | sterile mating technique | | | | | |
| | trapping | | | | | |
| | targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.) | | | | | |
| Crop specific practices | floating row covers | | | | | |

**This practice is used to manage this pest by at least some growers in the province.**

**This practice is not used by growers in the province to manage this pest.**

**This practice is not applicable for the management of this pest.**

**Information regarding the practice for this pest is unknown.**

[1]**Source: Allium crop stakeholders in reporting provinces (Ontario).**

**Table 11. Insecticides and bioinsecticides registered for the management of insect pests in allium crop production in Canada**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|
| abamectin | Avermectin, milbemycin | Chloride channel activator | 6 | R | Onion thrips |
| *Bacillus thuringiensis berliner* ssp. *kurstaki* strain HD-1 | *Bacillus thuringiensis* or *Bacillus sphaericus* and the insecticidal proteins they produce | Microbial disruptorof insect midgut membranes | 11A | R | Leek moth |
| chlorpyrifos (bulb onion and garlic only) | Organophosphate | Acetylcholinesterase inhibitor | 1B | RE | Onion maggot, cutworms (black, darksided, redbacked) |
| cyantraniliprole | Diamide | Ryanodine receptor modulators | 26 | R | Thrips (suppression) |
| cypermethrin (onion only) | Pyrethroid, Pyrethrin | Sodium channel modulators | 3A | RE | Onion maggot, thrips |
| cyromazine (dry bulb and green onion seed treatment only) | Cyromazine | Moulting disruptor, Dipteran | 17 | RE | For the importation of treated seed only for the control of onion maggot only |
| deltamethrin (onion only) | Pyrethroid, pyrethrin | Sodium channel modulator | 3A | RE | Onion thrips |
| diazinon (dry bulb and green onion only) | Organophosphate | Acetylcholinesterase inhibitor | 1B | Phase-out by December 31,2016 | Onion maggot larvae and flies, onion thrips |
| lambda-cyhalothrin | Pyrethroid, pyrethrin | Sodium channel modulator | 3A | RE | Onion thrips, leek moth |
| malathion | Organophosphate | Acetylcholinesterase inhibitor | 1B | R | Aphids, pea weevil, pea moth, leafhoppers, spider mites, thrips |
| naled | Organophosphate | Acetylcholinesterase inhibitor | 1B | R | Thrips, onion maggot |

...continued

**Table 11. Insecticides and bioinsecticides registered for the management of insect pests in allium crop production in Canada (continued)**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|
| permethrin (onion only) | Pyrethroid, pyrethrin | Sodium channel modulator | 3A | RE | cutworms (army, black, darksided, pale western, redbacked, white) |
| spinetoram | Spinosyn | Nicotinic acetylcholine receptor (nAChR) allosteric activator | 5 | | Suppression of onion thrips and leek moth |
| spinosad | Spinosyn | Nicotinic acetylcholine receptor (nAChR) allosteric activator | 5 | R | Suppression of onion thrips and leek moth |
| spirotetramat | Tetronic and Tetramic acid derivative | Inhibitors of acetyl CoA carboxylase | 23 | R | Onion thrips (larvae) |

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 23, 2014, on onion, shallot, leek and garlic unless otherwise specified. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (April 2012)* (www.irac-online.org) (accessed January 2014).

[3]PMRA re-evaluation status: R - full registration RE (yellow) - under re-evaluation , RES (yellow) - under special review as published in PMRA Re-evaluation note REV2013-06, *Special Review Initiation of 23 Active Ingredients*, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of November 15, 2013.

## Onion maggot (*Delia antiqua*)

### *Pest information*

*Damage:* Larvae of the onion maggot feed on onion roots. The most serious damage is due to early spring feeding by first generation onion maggots. Injury to very young onion seedlings may result in the plants withering away. At this time the larvae readily move between adjacent plants. Injury to older seedlings results in a yellowing and discolouration of the foliage, misshapen bulbs or rotting of the bulbs by secondary organisms in addition to feeding injury.

*Life cycle:* Onion maggot pupae overwinter in the soil. Adult flies emerge in the spring when the temperature warms up. Following mating, the females lay eggs in the soil adjacent to onion seedlings. After hatching, larvae feed on onion roots and at maturity move to the soil to pupate. There can be up to three generations per year depending on region.

### *Pest management*

*Cultural controls:* Diseased and weakened onions should be removed from the field as they are the preferred egg laying and feeding spots of the pest. Cull piles should be removed and cull onions should not be disked into the field, as this provides feeding grounds for successive maggot populations. Mechanical injury due to field operations should be minimized. A proper crop rotation should be used. Sticky traps and visual scouting can be used to monitor onion maggot populations and determine the need and timing for insecticide treatments for first generation onion maggots.

*Resistant cultivars:* None identified.

*Chemical controls:* Granular insecticides can be applied at seeding. This controls the majority of first and second generation maggots. If populations get above threshold, a foliar spray can be applied to control onion maggot flies.

### *Issues for onion maggot*

1. The onion maggot is an economically damaging problem in most allium crops. There is a need for the registration of reduced risk insecticides not in groups 3 or 1B, for resistance management.

## Onion thrips (*Thrips tabaci*)

### *Pest information*

*Damage:* Onion thrips have piercing mouthparts with which they suck juice from the leaves of onion plants. This feeding results in white streaks on the foliage which coalesce to form white blotches. The leaves of severely affected plants die back from the tips. Heavy thrips feeding can result in premature senescence of the plants and undersized bulbs. Damage is worse during hot and dry summers. Feeding by thrips often makes green onions and shallots unmarketable due to the unsightly blotches.

*Life cycle:* Onion thrips feed on many different vegetable, forage and weed hosts. The insect overwinters as an adult in onion refuse in the field and in a variety of crops and weeds. In the spring the adults lay their eggs on the leaves of onions and other host plants. Thrips may be wind-blown into onion crops from neighbouring fields. Infestations often begin at field borders. Nymphs feed on onion plants and then drop to the soil to pupate. There are several generations per year, depending on temperature. If temperatures remain above 32°C, a complete life cycle can take 12 days.

### *Pest management*

*Cultural controls:* Onions should be grown at least 2 km away from other host crops. Heavy rains or irrigation can reduce thrips populations. Weeds should be eliminated around the perimeter of the field. Onion debris and cull piles should be buried to eliminate overwintering sites. Onion thrips can be monitored by shaking sample plants over a white surface. In Quebec, a threshold has been established at three thrips per onion leaf.

*Resistant cultivars:* 'Grano' or 'Sweet Spanish' onions are resistant. Onions with a more open canopy tend to have less thrips problems.

*Chemical controls:* In the past, onion thrips were controlled by the same sprays used to control onion maggot. New integrated pest management practices and granular insecticides have reduced the number of foliar sprays applied for onion maggot, resulting in less control of onion thrips. Due to their behaviour, parts of the thrips population may be inaccessible to sprays and repeat treatments may be necessary. There can be high levels of resistance to insecticides in thrips populations, but resistance reverts over the winter months.

### *Issues for onion thrips*

1. The control of thrips can be very challenging for growers. The rapid reproduction of thrips following treatments and/or invasion from surrounding fields results in the need for frequent re-applications of pesticides. The development and registration of new reduced risk insecticides is required for onion thrips control.
2. There is concern over the development of resistance in onion thrips to lambda-cyhalothrin (a synthetic pyrethroid). Resistance to organophosphate insecticides has also been identified in some populations of onion thrips. The registration of new reduced risk insecticides is required and grower education to help reduce the chances of future resistance development.
3. An effective reduced risk strategy that includes alternatives to pyrethroid insecticides is needed to improve the control of onion thrips.
4. Research to identify the optimal method for insecticide application (water quantity, application time, adjuvant use, nozzle type, etc.) is needed for improving thrips control.

## Leek moth (*Acrolepiopsis assectella*)

### *Pest information*

*Damage:* The leek moth is an introduced pest that attacks onion, garlic, leeks chives, green onion and shallot, among other *Allium* spp. The larvae can cause significant injury by tunnelling within leaves or on leaf surfaces. Internal feeding on the leaves of onions and chives can result in translucent "windows".

*Life cycle:* The leek moth overwinters as adult moths or pupae. Following mating in the spring, eggs are laid on lower leaf surfaces. Following hatching, young larvae enter leaves and begin to feed, moving to the younger leaves in the centre of the plant. Larvae feed for several weeks and then exit the foliage to spin cocoons on the leaf surface. Adults emerge in 12 days. There can be up to 3 generations per season.

***Pest management***

*Cultural controls:* Activity of leek moths can be monitored using pheromone traps. The timing for insecticide applications can also be based on scouting. Sanitation practices including the removal of infested leaves and the elimination of crop debris following harvest may help to reduce numbers of the pest. Crop rotation and planting susceptible crops away from common sources would help to minimize leek moth attack. Injury from late season leek moths can be minimized by early harvest of the crop. The parasitoid *Diadromus pulchellus* has been introduced as a biological control agent of leek moth. Floating row covers have been shown to reduce damage from first and second generation larvae.

*Resistant cultivars:* None identified.

*Chemical controls:* Refer to "Table 11. Insecticides and bioinsecticides registered for the management of insect pests in allium crop production in Canada".

***Issues for leek moth***

1. There is a need for research and development of new reduced risk pesticides to fight against leek moth.
2. Access to pest management products must be improved for both conventional and organic producers.
3. There is a need for a forecasting model to be developed to predict timing of insecticide applications.

## Aster leafhopper (*Mycrosteles fascifrons*)

***Pest information***

*Damage:* Adult leafhoppers occasionally feed on onion. Although they do not cause noticeable direct feeding injury, they are a concern as they can transmit aster yellows disease. Leafhoppers feed on a broad range of plants with cereals and grasses being their preferred hosts.

*Life cycle:* Leafhoppers overwinter as eggs on winter cereals and grasses or are blown northward from overwintering sites in the United States. Eggs are laid on the underside of leaves of susceptible hosts. Following hatch, nymphs feed on host plants and develop into adults in two to three weeks. There are 2-5 generations per year.

***Pest management***

*Cultural controls:* Leafhopper populations can be monitored through the use of yellow sticky traps. Weeds on the perimeter of fields should be controlled, as they may be hosts. Host weeds include quackgrass, plantain, chickory, sowthistle, ragweed, Kentucky bluegrass, knotweed, pineappleweed, stinkweed, wild asters, lamb's-quarters and wild carrot.

*Resistant cultivars:* None identified.
*Chemical controls:* Refer to "Table 11. Insecticides and bioinsecticides registered for the management of insect pests in allium crop production in Canada".

### *Issues for Aster Leafhopper*

None identified.

## Black cutworm (*Agrotis ipsilon*)

### *Pest information*

*Damage:* Cutworms feed on foliage and cut stems of young plants at or below the soil line. The most serious feeding injury occurs in the early spring. Feeding occurs at night.
*Life cycle:* Cutworm moths are carried northward on winds from the United States in the early spring. Eggs are laid in weeds and following hatching, cutworm larvae may move into the crop to feed. Cutworm larvae may grow to 5cm long. At maturity, the larvae tunnel into the soil and pupate. Moths emerge through the larval tunnels. There are sometimes 2 generations in Canada, but usually only the first generation causes damage (early May and June). Cutworms are more commonly found in low lying areas of the field where there is standing moisture.

### *Pest management*

*Cultural controls:* Cultivation to destroy weeds and other vegetation 10 days before planting may reduce the number of larvae. The field and field perimeter should be kept as free of weeds as possible throughout the growing season. Proper drainage should be ensured with the installation of tile drains if needed. Cutworm larvae have several natural enemies. Unnecessary sprays should be avoided in order to conserve natural enemy populations.
*Resistant cultivars:* None identified
*Chemical controls:* Many of the pesticides used to control onion maggot also control cutworms.

### *Issues for cutworms*

None identified.

## Wireworms (*Elateridae*)

### *Pest information*

*Damage:* Wireworms feed on seeds and roots of plants, causing poor germination and weakened plants that often die or are non-productive. Damaged plants occur in a random pattern in the field. Many grass species are hosts for this pest.

*Life cycle:* Wireworms overwinter as larvae or adult beetles in the soil. Adults lay eggs in the spring near grass roots. The larval stage may require 2-5 or more years to complete. Pupation occurs in the soil.

***Pest management***

*Cultural controls:* As wireworms are attracted to pasture and grassland, onion should not be planted in a field the year after breaking sod to avoid wireworm populations in the soil. Grass weeds need to be controlled in crops following pasture or sod. Cultivation will expose larvae to predators. Wireworm populations may be monitored in the fall or early spring using bait stations or by field inspection in the spring.

*Resistant cultivars:* None available.

*Chemical controls:* None available.

***Issues for wireworms***

1. There is a need the development of new reduced risk pesticides to control wireworms.
2. Cultural methods (such as rotation) need to be investigated for the management of wireworm in onions.

## Weeds

### Key Issues

- Onions are poor competitors with weeds and significant crop loss due to weeds is possible. In addition, onions are sensitive to herbicide injury. There is a need for the development of an effective integrated approach to the management of weeds in onion crops.
- There is a need for the registration of herbicides that provide effective control of annual weeds, especially in organic soils.
- Herbicide resistance, including triazine resistance in lamb's-quarters and redroot pigweed resistance to oxyflourofen has been observed in some areas of Canada. There is a need for research and development of alternative control methods for these weeds.
- Barnyard grass (*Echinochloa crus-galli*) is becoming more difficult to control in onion.

## Table 12. Occurrence of weeds in allium crops in Canada[1,2]

| Pest | British Columbia | Manitoba | Ontario | Quebec | Nova Scotia |
|---|---|---|---|---|---|
| **Annual broadleaf weeds** | | | | | |
| Common chickweed | | | | | |
| Lamb's quarters | | | | | |
| Purslane | | | | | |
| Redroot pigweed | | | | | |
| Velvetleaf | | | | | |
| Wild buckwheat | | | | | |
| **Annual grasses** | | | | | |
| Smooth crabgrass | | | | | |
| Large crabgrass | | | | | |
| Green foxtail | | | | | |
| Yellow foxtail | | | | | |
| Giant foxtail | | | | | |
| **Perennial weeds** | | | | | |
| Quackgrass | | | | | |
| Field horsetail | | | | | |
| Yellow nutsedge | | | | | |

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest is present and of concern, however little is known of its distribution, frequency and importance.

Pest not present.

Data not reported.

[1]Source: Allium stakeholders in reporting provinces.

[2]Please refer to Appendix 1, for a detailed explanation of colour coding of occurrence data.

**Table 13. Adoption of weed management practices in onion, shallot, and leek production in Canada[1]**

| Practice / Pest | | Annual grasses | Annual broadleaf weeds | Perennial broadleaf weeds | Quackgrass | Yellow nutsedge |
|---|---|---|---|---|---|---|
| Avoidance | planting / harvest date adjustment | | | | | |
| | crop rotation | | | | | |
| | choice of planting site | | | | | |
| | optimizing fertilization | | | | | |
| | use of weed-free seed | | | | | |
| Prevention | equipment sanitation | | | | | |
| | mowing / mulching / flaming | | | | | |
| | modification of plant density (row or plant spacing; seeding) | | | | | |
| | seeding / planting depth | | | | | |
| | water / irrigation management | | | | | |
| | weed management in non-crop lands | | | | | |
| | weed management in non-crop years | | | | | |
| | tillage / cultivation | | | | | |
| Monitoring | scouting - field inspection | | | | | |
| | field mapping of weeds / record of resistant weeds | | | | | |
| | soil analysis | | | | | |
| | use of portable electronic devices in the field to access pest identification /management information | | | | | |
| | use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests | | | | | |
| Decision making tools | economic threshold | | | | | |
| | weather / weather-based forecast / predictive model | | | | | |
| | recommendation from crop specialist | | | | | |
| | first appearance of weed or weed growth stage | | | | | |
| | observed crop damage | | | | | |
| | crop stage | | | | | |

...continued

**Table 13. Adoption of weed management practices in onion, shallot, and leek production in Canada[1] (continued)**

| Practice / Pest | | Annual grasses | Annual broadleaf weeds | Perennial broadleaf weeds | Quackgrass | Yellow nutsedge |
|---|---|---|---|---|---|---|
| Suppression | pesticide rotation for resistance management | | | | | |
| | soil amendments | | | | | |
| | biological pesticides | | | | | |
| | arthropod biological control agents | | | | | |
| | habitat / environment management | | | | | |
| | ground cover / physical barriers | | | | | |
| | mechanical weed control | | | | | |
| | targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.) | | | | | |

**This practice is used to manage this pest by at least some growers in the province.**

**This practice is not used by growers in the province to manage this pest.**

**This practice is not applicable for the management of this pest.**

**Information regarding the practice for this pest is unknown.**

[1]**Source: Allium crop stakeholders in reporting provinces (Manitoba, Quebec and Nova Scotia).**

**Table 14. Adoption of weed management practices in garlic production in Canada[1]**

| Practice / Pest | | Annual grasses | Annual broadleaf weeds | Perennial broadleaf weeds | Quackgrass | Yellow nutsedge |
|---|---|---|---|---|---|---|
| Avoidance | planting / harvest date adjustment | | | | | |
| | crop rotation | | | | | |
| | choice of planting site | | | | | |
| | optimizing fertilization | | | | | |
| | use of weed-free seed | | | | | |
| Prevention | equipment sanitation | | | | | |
| | mowing / mulching / flaming | | | | | |
| | modification of plant density (row or plant spacing; seeding) | | | | | |
| | seeding / planting depth | | | | | |
| | water / irrigation management | | | | | |
| | weed management in non-crop lands | | | | | |
| | weed management in non-crop years | | | | | |
| | tillage / cultivation | | | | | |
| Monitoring | scouting - field inspection | | | | | |
| | field mapping of weeds / record of resistant weeds | | | | | |
| | soil analysis | | | | | |
| | use of portable electronic devices in the field to access pest identification /management information | | | | | |
| | use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests | | | | | |
| Decision making tools | economic threshold | | | | | |
| | weather / weather-based forecast / predictive model | | | | | |
| | recommendation from crop specialist | | | | | |
| | first appearance of weed or weed growth stage | | | | | |
| | observed crop damage | | | | | |
| | crop stage | | | | | |

...continued

**Table 14. Adoption of weed management practices in garlic production in Canada[1] (continued)**

| Practice / Pest | | Annual grasses | Annual broadleaf weeds | Perennial broadleaf weeds | Quackgrass | Yellow nutsedge |
|---|---|---|---|---|---|---|
| Suppression | pesticide rotation for resistance management | | | | | |
| | soil amendments | | | | | |
| | biological pesticides | | | | | |
| | arthropod biological control agents | | | | | |
| | habitat / environment management | | | | | |
| | ground cover / physical barriers | | | | | |
| | mechanical weed control | | | | | |
| | targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.) | | | | | |
| **This practice is used to manage this pest by at least some growers in the province.** | | | | | | |
| **This practice is not used by growers in the province to manage this pest.** | | | | | | |
| **This practice is not applicable for the management of this pest** | | | | | | |
| **Information regarding the practice for this pest is unknown.** | | | | | | |

[1]**Source: Allium crop stakeholders in reporting provinces (Ontario).**

**Table 15. Herbicides and bioherbicides registered for weed management in allium crop production in Canada**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|
| bromoxonil (garlic only) | Nitrile | Inhibition of photosynthesis at photosystem II | 6 | RES | Green smartweed, pale smartweed, lady's-thumb, wild mustard, kochia, cow cockle, Russian thistle, stinkweed, cocklebur, common ragweed, pigweed, velvetleaf, bluebur, American nightshade, wild buckwheat, tartary buckwheat, common buckwheat, common groundsel, lamb's-quarters |
| bromoxonil (dry bulb onion only) | Nitrile | Inhibition of photosynthesis at photosystem II | 6 | RES | Green smartweed, pale smartweed, lady's-thumb, wild mustard, kochia, cow cockle, Russian thistle, stinkweed, cocklebur, common ragweed, pigweed, velvetleaf, bluebur, American nightshade; common groundsel |
| carfentrazone-ethyl | Triazolinone | Inhibition of protoporphyrinogen oxidase (PPO) | 14 | R | Lamb's-quarters, morning glory, eastern black nightshade, redroot pigweed, velvet leaf, tall waterhemp, round-leaved mallow, hairy nightshade, field pennycress, prostrate pigweed, smooth pigweed, tumble pigweed, common purslane, Pennsylvania smartweed (seedling), tansy mustard, carpetweed, cocklebur, Jimsonweed, kochia, volunteer canola, glyphosate tolerant volunteer canola, burclover, prickly lettuce, Venice mallow, corn spurry |
| chlorthal-dimethyl (garlic and onion only) | Benzoic acid | Microtubule assembly inhibition | 3 | RES | Susceptable: lamb's-quarters, smooth crabgrass, large crabgrass, lovegrass, carpetweed, witchgrass, purslane, yellow foxtail, green foxtail, common chickweed; Moderately susceptible: redroot pigweed, barnyardgrass, goosegrass, groundcherry, annual bluegrass, johnsongrass (from seed) |

...continued

**Table 15. Herbicides and bioherbicides registered for weed management in allium crop production in Canada (continued)**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|
| clethodim (dry bulb onion only) | Cyclohexanedione 'DIM' | Inhibition of acetyl CoA carboxylase (ACCase) | 1 | RE | Annual grasses and volunteer cereals and corn; suppression of annual bluegrass and quack grass |
| diclofop-methyl (dry bulb onion only) | Aryloxyphenoxy-propionate 'FOP' | Inhibition of acetyl CoA carboxylase (ACCase) | 1 | R | Annual grasses: Wild oats, barnyardgrass, green and yellow foxtail, witchgrass, fall panicum, volunteer corn |
| dimethenamid-P (dry bulb and green only) | Chloroacetamide | Inhibition of cell division (Inhibition of VLCFAs) | 15 | R | Foxtail (green, yellow, giant), crabgrass (smooth, large), old witchgrass, barnyardgrass, fall panicum, redroot pigweed, western black nightshade, suppression of yellow nutsedge |
| diquat (dry bulb and green only) | Bipyridylium | Photosystem-I-electron diversion | 22 | R | Weeds; for use pre-emergent to crop, post-emergent to weeds on stale seedbed and inter-row directed weeding |
| fenoxaprop-p-ethyl (dry bulb onion only) | Aryloxyphenoxy-propionate 'FOP' | Inhibition of acetyl CoA carboxylase (ACCase) | 1 | R | Foxtail (green, yellow), barnyard grass, crabgrass, wild proso millet, fall panicum, old witch grass, volunteer corn |
| fluazifop-p-butyl (onion only) | Aryloxyphenoxy-propionate 'FOP' | Inhibition of acetyl CoA carboxylase (ACCase) | 1 | RES | Annual grasses and quack grass |
| flumioxazin (dry bulb onion only) | N-phenylphthalimide | Inhibition of protoporphyrinogen oxidase (PPO) | 14 | R | Redroot pigweed, green pigweed, common ragweed, lamb's-quarters, hairy nightshade, eastern black nightshade, kochia, Canada fleabane (Weeds only suppressed in muck soils and medium texture soils with <5% OM). |
| glufosinate ammoniun (onion only) | Phosphinic acid | Inhibition of glutamine synthetase | 10 | R | Annual grass and broadleaf weeds: common chickweed, green foxtail, lamb's-quarters, stinkweed, wild mustard, redroot pigweed, dandelion, oak-leaved goosefoot, wild buckwheat |
| napropamide (garlic only) | Acetamide | Inhibition of cell division (Inhibition of VLCFAs) | 15 | R | Annual weeds |

...continued

**Table 15. Herbicides and bioherbicides registered for weed management in allium crop production in Canada (continued)**

| Active Ingredient[1] | Classification[2] | Mode of Action[2] | Resistance Group[2] | Re-evaluation status[3] | Targeted Pests[1] |
|---|---|---|---|---|---|
| oxyfluorfen (dry bulb onion only) | Diphenylether | Inhibition of protoporphyrinogen oxidase (PPO) | 14 | R | Common purslane, redroot pigweed, cupped nightshade (potato weed), wild buckwheat, lamb's-quarters, oak-leaved goosefoot, maple-leaved goosefoot |
| paraquat (onion only) | Bipyridylium | Photosystem-I-electron diversion | 22 | RES | Many grasses and broadleaf weeds |
| pendimethalin (dry bulb onions, direct seeded only; green bunching onions, transplanted leeks only) | Dinitroaniline | Microtubule assembly inhibition | 3 | R | Barnyard grass, crabgrass, green foxtail, yellow foxtail, common chickweed, lamb's-quarters, pigweed (including triazine-resistant biotypes) |
| prometryne (leek only) | Triazine | Inhibition of photosynthesis at photosystem II | 5 | R | Most annual broad-leaved weeds and annual grasses including lamb's-quarters, redroot pigweed, wild mustard, purslane, lady's-thumb, corn spurry, hemp-nettle, common chickweed, western black nightshade and green foxtail |
| sethoxydim (onion dry bulb and garlic only) | Cyclohexanedione 'DIM' | Inhibition of acetyl CoA carboxylase (ACCase) | 1 | R | Annual grasses, wild oats, volunteer cereals, quackgrass |

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 23, 2014, on onion, shallot, leek and garlic unless otherwise specified. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2] Source: Herbicide Resistance Action Committee (HRAC). *Classification of Herbicides According to Site of Action* (www.hracglobal.com) (accessed January 2014). Herbicide resistance groups are based on the Weed Science Society of America classification system as reported by HRAC.(www.hracglobal.com).

[3]PMRA re-evaluation status: R - full registration RE (yellow) - under re-evaluation , RES (yellow) - under special review as published in PMRA Re-evaluation note REV2013-06, *Special Review Initiation of 23 Active Ingredients*, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of November 15, 2013.

## Annual and perennial weeds

### *Pest information*

*Damage:* Onions are poor competitors with weeds and significant crop loss due to weeds is possible. Broadleaf weeds can reach heights similar to that of onions and compete with the crop for light, water and nutrients. Grasses also cause significant problems in onion production because of their fast growth and ability to compete for necessary resources. Grass weeds can be very difficult to eliminate from infested fields and they require control prior to seed-set due to their prolific seeding. During harvest, weeds can interfere with harvesting equipment. In onion, the critical stage for the control of weeds is early in the growing season.

*Life cycle:* Annual weeds complete their life cycle in one year, going from seed germination through growth to new seed production. Winter annuals begin their growth in the fall, growing a rosette and producing their seeds early in the following year. Annual weeds are very adept at survival and dissemination through the production of large numbers of seeds. Most arable land is infested with annual weed seeds at all times and some weed seeds can remain viable in the soil for many years, germinating when conditions are suitable. Perennial weeds live for several to many years and generally establish from various types of root systems, although many will also spread by seeds. Tillage practices can break up underground root systems and aid in the spread of perennial weeds.

### *Pest management*

*Cultural controls:* An integrated approach for weed control is very important. Roadsides, ditches, and fence lines commonly host weed problems and should be kept as weed free as possible. Onions should not be planted into a field for which the weed history is unknown. Purchased seed should be certified to ensure that it contains the lowest possible quantities of weed seed. To reduce the transport of weeds by equipment, soil should be cleaned from equipment when leaving each field. Manure applications can also introduce weeds to a field. Crop rotation should be practiced.

*Resistant cultivars:* Onion varieties that have quick emergence and produce vigorous crop stands will shade out germinating weed seeds.

*Chemical controls:* Most annual broadleaf and grass weeds can be controlled in onions with a soil applied pre-emergent residual herbicide. This can provide season long protection against germinating weeds and seedlings. Once the crop emerges, there are limited herbicide options for controlling broadleaf weeds in the crop. The use of selective systemic herbicides can control grass that emerges after the crop.

### *Issues for annual weeds*

1. There is a need for development of an effective weed management program for onion production.
2. Redroot pigweed resistance to some herbicides has been observed in some areas. There is a need for the development of new reduced risk products for control of redroot pigweed.
3. Available herbicides do not provide adequate control of annual weeds especially in organic soils.

4. In some areas of Canada, annual weeds have developed resistance to herbicides. Triazine resistant lamb's quarters now infest many fields across the country. There is a need for the development of alternative control methods for annual weeds.
5. Barnyard grass (*Echinochloa crusgalli*) is becoming more of a problem and more difficult to control.
6. Improved alternatives to dimethenamid are needed as this herbicide only suppresses and delays weed growth and does not provide a long term solution.

## Resources

### IPM/ICM resources for production of Alliums in Canada

**Websites**

Agri-Reseau http://www.agrireseau.qc.ca

*Ontario Crop IPM* http://www.omafra.gov.on.ca/IPM/english/index.html

Sage Pesticides. http://www.sagepesticides.qc.ca/default.aspx

Health Canada, Pest Management Regulatory Agency
http://www.hc-sc.gc.ca/cps-spc/pest/index-eng.php

**Publications**

British Columbia Ministry of Agriculture crop publications
http://www.agf.gov.bc.ca/ahc/pahb/index.html

British Columbia Ministry of Agriculture. Vegetable Production Guide 2012: Beneficial Management Practices for Commercial growers in British Columbia (updated 28/01/2014)
http://www.agf.gov.bc.ca/cropprot/prodguide.htm

Howard, R.J., J.A. Garland and W.L. Seaman. Ed. (1994*). Diseases and Pests of Vegetable Crops in Canada*. Canadian Phytopathological Society and Entomological Society of Canada. Ottawa, ON. 554pp.

Manitoba Agriculture, Food and Rural Initiatives. Crops information.
http://www.gov.mb.ca/agriculture/crops/index.html

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 75, Guide to Weed Control 2014-15. 2014. http://www.omafra.gov.on.ca/english/crops/pub75/pub75toc.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. *OMAFRA Vegetables: Roots and bulbs, carrot, garlic, horseradish, leek, onion, parsnip, radish, rutabaga, shallots, sugarbeet, sweet potato, table beet* www.omafra.gov.on.ca/english/crops/hort/root_crops.html

Ontario Ministry of Agriculture, Food and Rural Affairs. *Vegetable Production Recommendations (2009-10) Publication 363);* Publication 363SE, Supplement - Vegetable Production Recommendations 2010-2011
http://www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Ontario Ministry of Agriculture, Food and Rural Affaires. Onions Publication 486 Agdex 258.
http://www.omafra.gov.on.ca/english/crops/pub486/p486order.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. Ontario Vegetable Crop Protection Guide (2012-13) Publication 838$^{E}$ and 2013 Supplement (838S)
http://www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Centre de Référence en Agriculture et Agroalimentaire du Québec.
http://www.craaq.qc.ca/

Ontario Ministry of Food and Rural Affairs Factsheets
http://omafra.gov.on.ca/english/crops/index.html

Ontario Ministry of Food and Rural Affairs. "Integrated Pest Management of Onions, Carrots, and Lettuce in Ontario".Publication 700, Agdex #252.
http://www.omafra.gov.on.ca/english/crops/pub700/p700order.htm

Perennia. Guide to Pest Management in Garlic. Nova Scotia Vegetable Crop Guide to Pest Management 2013.
http://perennia.ca/Pest%20Management%20Guides/Vegetables/2013/Garlic%202013.pdf

Perennia. Guide to Pest Management in Leeks. Nova Scotia Vegetable Crop Guide to Pest Management 2013.
http://perennia.ca/Pest%20Management%20Guides/Vegetables/2013/Leeks%202013.pdf

Perennia. Onion Management Schedule, A guide to weed, insect and disease management in dry bulb and green onions in Nova Scotia 2013.
http://perennia.ca/Pest%20Management%20Guides/Vegetables/2013/Onion%202013.pdf

## *Provincial Crop Specialists and Provincial Minor Use Coordinators*

| Province | Ministry | Crop Specialist | Minor Use Coordinator |
|---|---|---|---|
| **British-Columbia** | British Columbia Ministry of Agriculture and Lands<br>www.gov.bc.ca/al | Susan Smith<br>susan.l.smith@gov.bc.ca | Caroline Bédard<br>caroline.bédard@gov.bc.ca |
| **Manitoba** | Manitoba Agriculture, Food and Rural Initiatives<br>www.gov.mb.ca/agriculture/ | Vikram Bisht<br>vikram.bisht@gov.mb.ca | Jeanette Gaultier<br>jeanette.gaultier@gov.mb.ca |
| **Ontario** | Ontario Ministry of Agriculture and Food<br>www.omafra.gov.on.ca/english/ | Marion Paibomesai<br>marion.paibomesai@ontario.ca | Jim Chaput<br>jim.chaput@ontario.ca |
| **Quebec** | Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec<br>www.mapaq.gouv.qc.ca | Mario Leblanc<br>mario.leblanc@mapaq.gouv.qc.ca | Luc Urbain<br>luc.urbain@mapaq.gouv.qc.ca |
| **Nova Scotia** | Nova Scotia Department of Agriculture and Fisheries<br>www.novascotia.ca/agri | - | Steven Tattrie<br>tattrisc@gov.ns.ca |
| | Perennia<br>www.perennia.ca | Viliam Zvalo, Horticulture Crop Specialist (Kentville)<br>Vzvalo@perennia.ca | - |
| | | Rachael Cheverie, Horticulture Crop Specialist (Truro)<br>rcheverie@perennia.ca | - |

## *National and Provincial Vegetable Grower Organizations*

**Provincial**

British Columbia Potato and Vegetable Growers Association
http://www.bcfreshvegetables.com/bcfresh/associations

Conseil Québecois de l'horticulture (CQH) http://www.cqh.ca (The site is available in French only).

Horticulture Nova Scotia http://www.hortns.com/

Ontario Fruit and Vegetable Growers' Association http://www.ofvga.org

**National**

Canadian Horticultural Council http://www.hortcouncil.ca

## Appendix 1

**Definition of terms and colour coding for pest occurrence table of the crop profiles.**

Information on the occurrence of disease, insect and mite and weed pests in each province is provided in Tables 4, 7 and 11 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and importance in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th>Colour Code</th></tr>
<tr><td rowspan="13">Present</td><td rowspan="10">Data available</td><td>Frequency</td><td>Distribution</td><td>Pressure</td><td></td></tr>
<tr><td rowspan="5">**Yearly** - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">**Widespread** - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>**High** - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td>Red</td></tr>
<tr><td>**Moderate** - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>**Low** - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td>Yellow</td></tr>
<tr><td rowspan="3">**Localized** - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>**High** - see above</td><td>Orange</td></tr>
<tr><td>**Moderate** - see above</td><td>White</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="5">**Sporadic** - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">**Widespread** - as above</td><td>**High** - see above</td><td>Orange</td></tr>
<tr><td>**Moderate** - see above</td><td>Yellow</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="3">**Localized** - as above</td><td>**High** - see above</td><td>Yellow</td></tr>
<tr><td>**Moderate** -see above</td><td>White</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="2">Data **not** available</td><td colspan="3">**Not of concern:** The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="3">**Is of concern:** The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td></td></tr>
<tr><td>Not present</td><td colspan="4">The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.</td><td>Black</td></tr>
<tr><td>Data not reported</td><td colspan="4">Information on the pest in this province is unknown. No data is being reported for this pest.</td><td>Grey</td></tr>
</table>

## References


Chaput, J. 1995. *Identification of Diseases and Disorders of Onions.* Ontario Ministry of Agriculture, Food and Rural Affairs.

Howard, R., J. Allan Garland, and W. Lloyd Seaman. 1994. *Diseases and Pests of Vegetable Crops in Canada.* Canadian Phytopathological Society and Entomological Society of Canada. Ottawa, Ontario.

Ontario Ministry of Agriculture and Food. Hort Matters. *Update on stemphylium leaf blight of onions in Ontario.* July 6, 2012 http://www.omafra.gov.on.ca/english/crops/hort/news/hortmatt/2012/19hrt12a6.htm (Accessed January 22, 2012)

Ontario Ministry of Agriculture and Food. *Garlic Production* Agdex 258/13. http://www.omafra.gov.on.ca/english/crops/facts/09-011w.htm

Ontario Ministry of Agriculture and Food. *Leek Production.* Agdex 258/20. http://www.omafra.gov.on.ca/english/crops/facts/91-004.htm

Ontario Ministry of Agriculture and Food. *Shallots: What they are and how to grow them.* Agdex 250. http://www.omafra.gov.on.ca/english/crops/facts/98-037.htm

Ontario Ministère de l'Agriculture et de ''Alimentation. Carnet horticole. *Mise à jour sur la stemphuliose dans les cultures d'oignons en Ontario.* 09 juillet 2012

http://www.omafra.gov.on.ca/french/crops/hort/news/hortmatt/2012/19hrt12a6.htm (site consulté 22 janvier 2014.

Réseau d'Avertissements Phytosanitaires, *Avertissement.* 2002. Ministère de l'Agriculture, Pêcheries et Alimentation. http://www.agr.gouv.qc.ca/dgpar/rap. (Accessed Mar, 2005)

Schwartz, H. 2002. *Botrytis, Downy Mildew, and Purple Blotch of Onion.* Colorado State University Cooperative Extension.

http://www.ext.colostate.edu/pubs/crops/02941.html.